DOCUMENT RESUME

ED 068 974 24 CS 200 224

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TITLE Effects of Pronouns on Children's Memory for Sentences.
INSTITUTION Pittsburgh Univ., Pa. Learning Research and Development Center.
SPONS AGENCY Office of Education (DHEW), Washington, D.C. Bureau of Research.
BUREAU NO BR-5-0253
PUB DATE 72
CONTRACT OEC-4-10-158
NOTE 20p.

EDRS PRICE MF-$0.65 HC-$3.29
DESCRIPTORS Child Language; Children; *Comprehension; *Integrated Activities; *Memory; *Pronouns; Retention; Surface Structure

ABSTRACT

Do children integrate pronoun sentences in memory as adults seem to do, i.e., processing anaphoric reference between two propositions into a form in which their common element is represented only once (jointly) for the two propositions? Data from two experiments involving third and fourth grade students revealed that a few very vivid sentences were integrated, which suggests that the ability to integrate anaphorically linked propositions precedes the ability to analyze all clauses into forms that are appropriate operands for the integration function. The subjects knew the anaphoric structure but could not process individual propositions to the point where the rules applied mediated memory. Furthermore, when the sentence subjects were repeated rather than pronominalized, the sentences were not uniformly integrated in memory. This inability to integrate sentence memory representations was attributed to short memory limitations that prevented successful anaphora resolution. (HS)

LEARNING RESEARCH AND DEVELOPMENT CENTER

1972/17

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ED 068974

CS 200 214

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1972

The research reported herein was supported by the Learning Research and Development Center supported in part by funds from the United States Office of Education, Department of Health, Education, and Welfare. The opinions expressed in this publication do not necessarily reflect the position or policy of the Office of Education and no official endorsement should be inferred.

Abstract

Children, eight to ten years old, were quite able to comprehend personal pronouns. However, they did not remember sentences whose propositions were linked by pronouns in the integrated manner that adults do. Integration was found only with a few, very vivid sentences. When the sentence subjects were repeated rather than pronominalized, the sentences were uniformly not integrated in memory. Children's inability to integrate sentence memory representations was attributed to short-term memory limitations that prevented successful anaphora resolution.

Effects of Pronouns on Children's Memory for Sentences[1]

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A recent study (Lesgold, 1972) presents evidence that sentences which contain pronouns have a somewhat different representation in memory than sentences that are otherwise the same but without anaphoric reference. This was demonstrated with sentences like (1) and (2), which are identical in surface structure, and with sentences like (3) and (4), which are identical in underlying propositional structure. In either case, the pronoun form was remembered in an integrated manner. That is, a probe word elicits lexical words from its own proposition and from propositions tied to its own proposition by pronominal reference with equal likelihood. For example, pie should cue senile and ate with equal likelihood in recall of (1). Lesgold showed that, averaging over all possible lexical item probes, this was true for sentences like (1) and (3) but was not true for sentences like (2) and (4), where probes were especially effective within their own propositions.

(1) The aunt was senile and she ate the pie.

(2) The aunt was senile and Alice ate the pie.

(3) The blacksmith who was skilled pounded the anvil which was dented.

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[1]The experiments were conducted by Hildrene DeGood. Charles Perfetti and Eric Jacobson provided useful criticism of a previous draft.

(4) The blacksmith was skilled and the anvil was dented and the blacksmith pounded the anvil.

From this result in adults, it was argued that pronoun reference, and perhaps anaphoric reference in general, between two propositions results in those propositions being processed into a form in which their common element is represented only once--jointly--for the two propositions. Further, when a common element of two propositions is not "flagged" in the sentence's surface form (e.g., with a pronoun), this joint representation is less likely. The present study examines the memory of children who have recently acquired demonstrable ability to comprehend pronouns in order to determine whether unification of memorial structure for pronoun sentences is an immediate and automatic result of the manner in which pronouns are comprehended or whether pronoun comprehension ability precedes the adult-like memory representation in development.

By definition, an anaphoric structure is one which refers back for part of its meaning to an earlier part of the discourse, to its referent. Pronouns, like any other anaphora, can only be adequately comprehended via some reference back either to an earlier portion of the text or to some underlying information that has already been extracted from that earlier text portion. At the time that meaning is assigned to the pronoun, some sort of reference information must be available for that assignment to be properly made. This study addresses the question of whether this inevitable constraint upon the operation of a comprehender that understands pronouns is the cause of the unification results or whether some additional, separately acquired ability merely makes use of this constraint.

One way to illustrate this distinction is to assume a particular general model of memory and then see how the particulars of that model may vary depending upon whether unified sentence memory is the immediate result of anaphora processing capability or whether additional learning is required. Consider the class of "buffer models" in which long-term memory for an item is a function of the amount of time the item spent in short-term memory (STM). Such models have been shown to be very adequate for simple verbal learning tasks (Shiffrin & Atkinson, 1969) and recognition for pictures (Loftus, 1971). The model might also be adopted to sentence memory, by specifying which sentence-derived structures co-occur in STM during the comprehension of a sentence. One possibility is that part or all of the sentence propositions' representations must co-occur in STM due to the nature of the comprehension process and that this automatic co-occurrence is the cause of unified sentence memory. The alternative is that simply comprehending the sentences does not produce unified memory, that additional study skills must be applied.

Two of the things that are produced by comprehenders are representations of the underlying predication structure of text and information about the identity of or relationships between the operands in that predication structure. The latter arise from anaphora processing, and the former from more general grammatical and semantic analysis of text. It is not unreasonable to expect that every predication spends some time in STM. Anaphora processing, to the extent that it consists of holding a partial structure containing the anaphora in STM while doing processing for its referent, must also produce occasions when STM contains both an anaphora structure and its referent structure. The automatic-processing hypothesis concerns the forms for those two structures. It asserts that during the processing of pronouns,

the structure of predications involving the pronoun and that involving the referent co-occur in STM, and are automatically present there long enough for unified sentence information to transfer to LTM.

On the other hand, the integration effect may be due to additional comprehension or study skills beyond those sufficient to produce comprehension. In addition to using knowledge of pronominal structure to understand sentences with pronouns, people may use that knowledge to devise a particular strategy for the storage of pronoun sentences in integrated form. They may, for example, notice an anaphoric relationship between two propositions and decide to rehearse parts of those propositions together. Alternatively, they may construct and remember images which are integrated representations of the anaphora-connected units. To the extent that this memory processing is not the automatic result of comprehension processing, the processing skills for each type of processing may be separately learned. That is, one might learn to understand pronoun sentences before one has long-term memory capability for them.

According to the automatic-processing hypothesis, whenever we find a person who is able to comprehend sentences that contain pronouns, such a person should demonstrate the same kind of pronoun-sentence integration as was demonstrated in Lesgold (1972). On the other hand, if we can find people who understand pronouns and can accurately comprehend pronoun sentences but who do not show sentence integration, then we must conclude that the automatic-processing hypothesis is incorrect, that there exists a period of time during which subjects are already able to understand pronouns but have not as yet acquired the ability to use their knowledge of pronoun-sentence structure to integrate sentences in memory. Children are most likely to be

the critical subjects for this test. If we examine children of an appropriate age, children who have just learned to correctly comprehend pronoun sentences, we should be able to determine if there are any children who can comprehend the pronoun sentences but do not show sentence integration.

The present experiment does exactly this. It looks at third and fourth grade children, tests to see whether or not they understand pronoun sentences, and then separately examines their memory for other pronoun sentences to determine whether sentence propositions connected by pronouns are integrated.

Experiment 1

Method

Subjects. Thirty-one students from a campus laboratory school participated in this experiment.[2] All were from the group equivalent to third and fourth grades and ranged in age from eight to ten years with a median of 8.8.

Design and materials. A comprehension test was constructed testing knowledge of 14 anaphoric structures. It contained three items for each structure, but of the 42 items, only three are relevant to this report. The following was one of the critical items, and the other two are similar in form.

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[2]Subjects were obtained from Falk School, University of Pittsburgh, through the kind assistance of its Assistant Director, Roy Creek.

The old man likes candy. He is fat. The boy is eating a piece of cake. He likes to ride his bike. Who is fat?

Eight sentences were constructed for the second part of the task, all of the same formats as in (5) and (6) below. This format can be symbolized as: $\underline{S}\ \underline{V}_1$ 'ed the $\underline{O}_1$ and $\left\{\begin{matrix}\underline{S} \\ \text{he/she}\end{matrix}\right\}\ \underline{V}_2$ 'ed the $\underline{O}_2$. These were divided into two groups of four which were presented and tested separately. Within a group of four, two of the sentences were in the pronoun form (5) and two were in the repeated-noun format (6). For half the Ss, this assignment was reversed. Thus, S received four pronoun and four repeated-noun sentences. There were four possible probes for each sentence ($\underline{V}_1$, $\underline{O}_1$, $\underline{V}_2$, $\underline{O}_2$), and the assignment of probes to sentences could be completely counterbalanced with four test forms. There were two presentation forms so a completely counterbalanced replication requires eight Ss. Three complete replications were run and a fourth was short one S due to exhaustion of the subject pool.

(5) Randy played drums and he wrote stories.

(6) Randy played drums and Randy wrote stories.

Procedure. Subjects first completed the comprehension test unpaced. They would read each passage and then orally answer the question. For reasons beyond the scope of this report, approximately half of the Ss heard a tape recording of each passage and question while they were reading the printed form. After completing the comprehension test, S received instructions about the sentence memory task. It was emphasized that S should try to recall each of the sentences and that if he could not recall the sentence exactly he should report any words he remembered from the sentences. Each of the

first four sentences was then shown individually for ten seconds. During that interval, E read the sentence aloud. After seeing all four sentences, S began an oral recall procedure in which he was asked, "Do you remember anything from the sentence that had _____ in it?" The study and test procedures were then repeated for the second four sentences. All responses to the comprehension items and to memory probes were taped.

Scoring. The comprehension items were scored using the procedure of Bormuth, Manning, Carr, and Pearson (1970). This procedure accepts the referent of the pronoun or any correct semantic substitute for that referent as correct. Two observers agreed completely on the scoring of these items. The sentence recall was scored on the basis of specific recall of the verbs and objects of the sentences. Whenever a word other than the exact sentence word was recalled, its adequacy as a semantic substitute was judged by an observer who was not told the condition from which that item came.

Results

Comprehension of pronouns. Twenty-seven of the Ss correctly answered all three personal pronoun comprehension items, and the remaining four correctly answered two out of three. This level of performance, in which correct comprehension occurs 96% of the time, would appear to satisfy the requirement of a population which understands personal pronouns.

Sentence memory. Lexical item recall was tabulated according to whether the recalled item was in the same sentence proposition as the probe word or not. If there is complete integration of sentences,

then there should be no difference in the level of recall for items in the same proposition as the probe ("same" items) or for items in the other proposition from the probe ("other" items). For the pronoun sentences, 47% of the "same" items and 12% of the "other" items were correctly recalled. For the repeated-noun sentences, the recall was 55% and 16%, respectively. The advantage of the repeated-noun condition over the pronoun condition was not significant, $t(30) = 1.14$.

Since there are twice as many "other" items to be recalled as "same" items, the integration hypothesis predicts that one-third of the responses should be "same" items. The proportion of "sames" was computed separately for each subject in each condition for purposes of statistical analysis. The mean proportion of "sames" was identically .66 for each condition. This was significantly higher than the expected .33, $t(30) = 7.73$, $p < .001$. These tests were performed on arcsine transforms of Ss' proportion-of-same scores, but the same statistical decisions can be made from equivalent analyses of the raw proportions.

Experiment 2

The above results appear to indicate that pronoun sentences are not completely integrated in memory by children who understand pronouns. However, the small number of sentences tested and the incompleteness of the design suggest that a replication is in order. The experiment to be described replicates the design of Exp. 1, but with twice as many sentences.

Method

Subjects. Thirty-seven students in an urban public school participated as subjects.[3] They ranged in age from 8.0 to 11.5 years with a median of 9.4. All were in third or fourth grade and had scores of third to fifth stanines on the Total Reading portion of the Metropolitan Achievement Tests.

Design and materials. Materials were identical to those of Exp. 1, except that an additional eight sentences were added to the eight available from Exp. 1.

Procedure. The procedure was identical to that in Exp. 1, except that the study-test regime was repeated a total of four times to accommodate the 16 sentences.

Results

Comprehension of pronouns. Of the 37 Ss, 25 (68%) correctly answered all three comprehension items, 11 (30%) answered two of three, and one answered but one of the three items. This amounts to an average comprehension score of 88% for the group, indicating generally good understanding of the personal pronoun form.

Sentence memory. The same lexical item tabulations were made as in Exp. 1. For the pronoun sentences, 46% of the "same" items and 14% of the "other" items were recalled. The comparable figures for the repeated-noun sentences are 48% and 22%, respectively.

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[3] Subjects were obtained from A. Leo Weil School, Pittsburgh Board of Public Education, through the kind assistance of its Principal, Lloyd Briscoe.

The advantage of the repeated-noun condition over the pronoun condition was not significant, $t(36) = 1.31$. The proportion of "sames," expected to be .33 if sentences are integrated in memory, was actually .52 for the pronoun sentences and .58 for the repeated-noun sentences. The two conditions did not differ significantly, $t(36) = 1.52$, but the proportion of "sames" was significantly greater than .33, indicating incomplete integration, $t(36) = 9.72$, $p < .001$.

One can reasonably object that these data include subjects who could not answer all three personal pronoun comprehension items. To counter this objection, separate analyses were made of the first 16 Ss to provide two complete replications of the experimental design (several sentence-probe combinations only had two replications by perfect personal-pronoun comprehenders). For these subjects, there again was no difference between recall of pronoun vs. recall of repeated-noun sentences, $t(15) = .22$. Again, the proportions of "sames" for the pronoun and repeated-noun sentences, .48 and .53 respectively, were not significantly different, $t(15) = .85$, but the "same" proportion was significantly greater than the .33 perfect-integration value, $t(15) = 6.61$, $p < .001$.

The data for the perfect-comprehension, complete-design subset thus accurately mirror the findings for all 37 Ss. There is no difference between pronoun and repeated-noun sentences for these children and there is generally incomplete integration of sentences, in contrast to the complete integration that adult Ss show (Lesgold, 1972).

To ascertain whether there is any hint of integration, additional analyses were performed on data for the four best- and four worst-recalled sentences. For the four worst-recalled sentences, 10% of the pronoun forms and 12% of the repeated-noun forms were recalled,

while for the four best-recalled sentences, the recall figures were 34% and 25%, respectively. The general difference between recall of the two sets of sentences was significant, $t(36) = 10.7$, $p < .001$. The design does not permit comparison of the pronoun vs. repeated-noun interaction with general recallability, but the apparent advantage of pronoun sentences is worth noting, as it conforms more closely to the expected behavior for adults (Lesgold, 1972).

The proportion of "same" responses for the best sentences was .44 and for the worst sentences was .62. The difference was significant, $t(36) = 2.51$, $p < .02$. Further, the best sentences were still not completely integrated--the proportion of sames was significantly greater than the expected 33%, $t(36) = 2.84$, $p < .01$.

These best vs. worst analyses can also be performed on the perfect-comprehension, complete-design subset of 16 Ss. There the most important results are that the proportion of "sames," .37, is not significantly greater than .33, $t(15) = 1.13$; while the proportion of "sames" for the worst sentences, .52, is still significantly in excess of the perfect-integration figure of .33, $t(15) = 1.96$, $p < .05$ (one-tailed). Recall was 48% for the best sentences and 15% for the worst. These totals differed significantly, $t(15) = 7.87$, $p < .01$.

Discussion

The data clearly indicate that school children about nine years old do not generally integrate pronoun sentences in memory as adults seem to do. According to the argument above, this is to be interpreted as evidence for the hypothesis that additional skill beyond sufficient pronoun comprehension ability is required for adult-like sentence

memory. This interpretation is complicated, however, by the unexpected result of complete integration of the best-recalled sentences by the 16-subject subset. Charges of "proving the null hypothesis" aside, the best-recalled sentences are clearly better integrated than the worst-recalled. If there are additional operations in the comprehension-study process that are necessary to integrated memory, then these additional operations appear to be effective for only some sentences. There is something beyond simple pronoun comprehension ability that is required for sentence integration, and the nature of that additional ability is that it is present for some sentences earlier than for others. The distinguishing properties of easily integrable sentences are not immediately apparent.

In the present case, the four best-recalled sentences of Exp. 2 are all sentences that were added to the original pool of eight used in Exp. 1, while the four worst-recalled sentences are all members of the original pool. We have found no quantitative differences, such as frequency in third-grade reading material or imagery value (Paivio, Yuille, & Madigan, 1968), between the words in the two sets of sentences. When four elementary-school teachers and reading specialists were asked to rate the sentences for the extent to which they portrayed actions that were "exciting and vivid to third graders," they rated the best-recalled sentences higher than the worst-recalled sentences, but the two groups of scores did overlap. Sentence (7) is an example of one of the best-recalled sentences and (8) is an example of one of the worst-recalled. The reader will probably share our view that there is some difference along a dimension such as vividness, but the exact difference has yet to be characterized. Further, there may be no causal relationship between imagery value, or vividness, and integration. These may be separate factors that both affect performance.

(7) Peter fried an egg and he blew his nose.

(8) Mark bakes cookies and he grows flowers.

The fact that some sentences were integrated by our nine-year-old subjects and that adults integrate pronoun sentences regularly strongly suggests, then, that the ability to integrate propositions that are anaphorically linked is present before the ability to analyze all clauses into propositional forms that are appropriate operands for the integration function. Our subjects presumably knew the basic anaphora structure rules but could not process individual propositions to the point where those rules could be applied in a manner that mediated memory.

The fact that this is a memory task places a stronger burden on STM, in terms of the amount of proposition processing that must be performed before the anaphora relationship can be used to produce an integrated code. All of the information from both propositions would, presumably, have to be in STM at the same time before any integrated code could be transferred to long-term memory. If this were not necessary, then perhaps the anaphora processing might be more discernible. Such a situation in which anaphora processing may occur with less STM load is present in many reading comprehension tests, including the criterion task for the present experiments. There, the subject can use the printed page as an external storage device to augment STM.

The other comprehension items tested in conjunction with the present study did provide evidence for this surface processing on several occasions. Consider the following item, which tests the pro-adverb form:

My brother works in a steel mill. He plays football in the park. Now he is in the house. He likes to be there.

Where does he like to be?

To answer this question, the subject must know how to interpret there. Some subjects do this without using much STM, by surface-level processing for an appropriate antecedent piece of text. Instead of answering "in the house" or "He likes to be in the house," such a subject recites the part of the passage that contains the antecedent: "Now he is in the house." Similar protocols were found with other anaphora structures as well.

Even this surface structure processing involves some operating memory, and one would expect that hard enough processing tasks would fail to benefit from external storage. Work of a very different nature by Donaldson (1963) suggests that this is indeed the case. She examined children's problem solving, varying both problem difficulty and subjects' age. We shall be concerned with her ten-year-old subjects and their solution of two types of three-term series problems. The first type is a quantified problem.

"We want to find out the ages of two girls called Jean and May. We know that a third girl Betty is 15, and that she is 3 years older than one of the two girls and 5 years older than the other. If we had one more piece of information we could calculate the ages of Jean and May. What is that piece of information?
(Donaldson, p. 251)"

Children do make some errors on this problem, but their protocols do not suggest that they lose track of the three characters. They seem to adequately comprehend the pronoun she.

Betty is the middle term of the above problem and pronominal reference to her was understood correctly. Consider now what happens to Dick, the middle term in the following unquantified three-term series problem:

> "Tom is taller than Dick.
>
> "Dick is taller than John.
>
> "Which of these three boys is the tallest?
>
> (p. 251)"

Here, a number of subjects conclude that there are two different Dicks. This is well illustrated by part of one of Donaldson's protocols:

> "It's Tom. Tom is taller than Dick so Dick is small. And Dick here [points to the second premiss] is taller than this Dick here [points to the first premiss] . . . . (p. 117)"

The subject goes on to respond "Four" when asked how many people the problem talks about, indicating incorrect comprehension of the referential repetition anaphora. Even with the external storage capacity generated by the problem being on the printed page, the processing necessary to both handle the problem statements and process the anaphora appears to be lacking.

Combined with these anecdotal data, the data of the experiments above suggest that (a) eight- to ten-year-old children know the basic anaphora structures, but that (b) various processing constraints,

notably STM limitations, reduce their ability to complete anaphora comprehension processing. There is no reason to assume that a special strategy beyond ordinary anaphora comprehension capacity plays a role in determining integration effects in memory. Rather, it appears that anaphora comprehension rules will automatically produce integrated memory representation, as long as S has learned to represent individual propositions efficiently enough so that they can "fit" into limited STM simultaneously.

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